Analysis of the Trade-Off between Sensitivity and Resolution of a Pinhole Collimator for SPECT

Karen Van Audenhaege, Roel Van Holen, Stefaan Vandenberghe

Objectives

It is our goal to find out whether a high-resolution brain SPECT system would result in a better image quality than a lower-resolution system with a higher sensitivity.

Methods

To answer this question, a single pinhole collimator is simulated using a ray tracer algorithm (Siddon 1985) that includes resolution modeling and pinhole penetration. The system consists of one large detector (258 x 1148 mm^2) with 4.3 x 4.3 mm^2 pixels and a radius of rotation of 477 mm. The distance between the pinhole and the axis of rotation is 139 mm and the pinhole diameter is changed over 3 different setups to achieve different resolutions. The pinhole diameter is respectively 2 mm, 3.9 mm and 5.4 mm, which results in a volume sensitivity of respectively 4.4e-05, 1.5e-04 and 2.8e-04 cps/mm^3. To model sensitivity, poisson noise is added to the projection data. A scan time of 30 min and a total activity of 30 mCi is assumed. The study is repeated for 300mCi. Reconstructions are performed with the Ordered Subsets Expectation Maximization algorithm (OSEM, 8 subsets) with resolution recovery and correction for pinhole penetration. The voxel size is 1 mm^3. Image quality is assessed by calculating Contrast Recovery Coefficients (CRC) in a cylindrical phantom with a diameter of 220 mm and a length of 124 mm. The phantom has hot spheres with a sphere:background activity of 7:1 (the dimensions are 4, 6 and 8 mm) and cold spheres with dimensions 6 and 8 mm.

Results

The results show that at 300 mCi, the smallest pinhole (with a diameter of 2.0 mm) gives the best image quality, while at 30 mCi it is better to give up some resolution for a higher sensitivity. The pinhole with a diameter of 3.9 mm then gives the highest contrast.

Conclusions

Smaller pinholes lead to an improvement in spatial resolution but also a loss in sensitivity. When the scan time is limited, the gain in resolution does not compensate for the loss in sensitivity.

Supporting data

The results are summarized in two tables. The CRC is shown at 40% noise and at 13% noise for the different setups at 30mCi and 300mCi. Each setup was

simulated 3 times and both the mean and the standard deviation of the results are shown.

Additionally, a Derenzo phantom was projected and reconstructed. The phantom has hot spheres with a sphere:background activity of 7:1 (the dimensions are 3, 4, 6, 8 , 10 and 12 mm). 40 iterations and 8 subsets were used and the image was post-smoothed with a Gaussian filter with a Full-Width-At-Half-Maximum of 3 mm. The simulation was performed with 30mCi activity and 30 min scan time. The results also show that the pinhole with a diameter of 3.9 mm gives the best results.

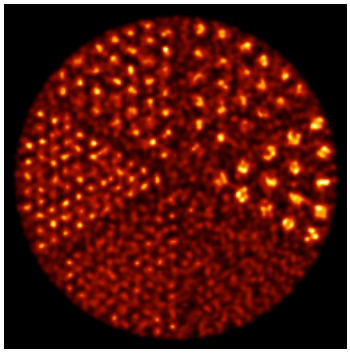
30mCi at 40% Noise

	4 mm hot sphere	6 mm hot sphere	8 mm hot sphere	6mm cold shpere	8 mm cold sphere
2 mm pinhole	μ=32%, σ=12%	μ=69%, σ=7.0%	μ=76%, σ=1.6%	μ=15.7%, σ=3.5%	μ=49%, σ=7.5%
3.9 mm pinhole	μ=33%, σ=5%	μ=69%, σ=2.5%	μ=77%, σ=1.5%	μ=24%, σ=7.3%	μ=54%, σ=12.7%
5.4 mm pinhole	μ=20%, σ=1.6%	μ=57%, σ=1.4%	μ=73%, σ=1.4%	μ=20%, σ=7.5%	μ=52%, σ=2%

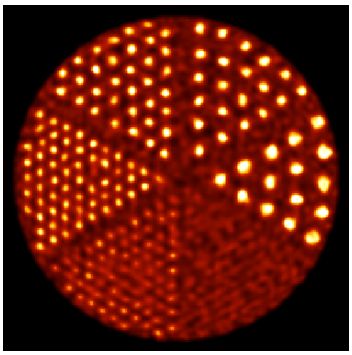
300mCi at 13% Noise

	4 mm hot sphere	6 mm hot sphere	8 mm hot sphere	6mm cold shpere	8 mm cold sphere
2 mm pinhole	μ=38%, σ=2.4%	μ=66%, σ=0.7%	μ=76%, σ=0.7%	μ=15.9%, σ=4.2%	μ=46%, σ=1.5%
3.9 mm pinhole	μ=32%, σ=1.1%	μ=65%, σ=2.0%	μ=76%, σ=1.0%	μ=21.5%, σ=4.7%	μ=57%, σ=2.5%
5.4 mm pinhole	μ=20.5%, σ=1.2%	μ=54%, σ=1.0%	μ=74%, σ=0.4%	μ=22.6%, σ=0.5%	μ=51%, σ=1.6%

Pinhole diameter: 2 mm



Pinhole diameter: 3.9 mm



Pinhole diameter: 5.4 mm